

**IG-01-042**

# **AUDIT REPORT**

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## **SAFETY OF LIFTING DEVICES AND EQUIPMENT AT STENNIS SPACE CENTER**

**September 28, 2001**

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National Aeronautics and  
Space Administration

**OFFICE OF INSPECTOR GENERAL**

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## **Acronyms**

CMMS	Computerized Maintenance Management System
DCMA	Defense Contract Management Agency
FMEA	Failure Mode and Effects Analysis
FOSC	Facility Operations Support Contractor
LDE	Lifting Devices and Equipment
MSS	Mississippi Space Services
NACB	North American Crane Bureau
NSS/GO	NASA Safety Standard/Ground Operations
OI	Operating Instruction
PM	Preventive Maintenance
S&MA	Safety and Mission Assurance
SPG	Stennis Procedures and Guidelines

W

September 28, 2001

TO: A/Administrator

FROM: W/Inspector General

SUBJECT: INFORMATION: Safety of Lifting Devices and Equipment  
at Stennis Space Center  
Report Number IG-01-042

The NASA Office of Inspector General has completed an audit of Safety of Lifting Devices and Equipment (LDE)<sup>1</sup> at the John C. Stennis Space Center (Stennis). As early as 1997, the NASA Office of Safety and Mission Assurance (S&MA) began reporting safety deficiencies with the Stennis LDE program. Since then, other parties, both internal and external to Stennis, have reported safety deficiencies within the LDE program. Our audit confirmed many of those issues and focused on five major areas of concern. Specifically, we found that Stennis did not safely perform critical lifts,<sup>2</sup> operators and riggers were not properly trained and certified, operators used cranes with safety deficiencies, and crane maintenance and inspections were inadequate. Despite being advised of many of those conditions in mishap reports, independent inspections, and internal assessments, significant deficiencies in LDE management at Stennis continued to exist. As a result, during 1999-2000, Stennis removed 16 critical lift cranes from service and reported two lifting mishaps<sup>3</sup> that resulted in equipment and facility damages with estimated costs of more than \$550,000.

Although Stennis has made some improvements in the safety of its LDE program, additional management emphasis and improvements are needed. Unless Stennis makes those improvements, the potential exists for harm to personnel and assets essential to NASA's space propulsion program and for future monetary losses.

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<sup>1</sup> LDE include overhead and mobile cranes, derricks, hoists, and hoist-supported personnel lifting devices.

<sup>2</sup> Lifts of high-dollar items such as NASA's space hardware, one-of-a-kind test articles, major facility components, or personnel are considered critical lifts.

<sup>3</sup> The mishaps occurred on June 23, 1999, and November 5, 2000, during use of the B-Test Stand main derrick. The 1999 mishap occurred during a Boeing lift of a commercial engine. The main 200-ton hook traveled upward until the lower sheave block contacted the upper-fixed sheave block. The two-blocking incident resulted in approximately \$350,000 in damages. The 2000 mishap occurred during a Lockheed-Martin lift when the rigging for a man-lift failed. The man-lift was destroyed after falling approximately 80 feet. The mishap resulted in more than \$200,000 in damages.

## **Background**

NASA established safety requirements for the design, testing, inspection, personnel certification, maintenance, and use of LDE at NASA Centers in the NASA Safety Standard/Ground Operations (NSS/GO) 1740.9B, "Safety Standard for LDE," dated November 1991.<sup>4</sup> Compliance with the standard is mandatory for all NASA-owned and contractor-supplied equipment used in support of Agency operations at NASA installations.

The NASA S&MA Office performs process verification reviews at the Centers to determine compliance with the LDE safety standard. Headquarters' S&MA officials reported recurring deficiencies in the Stennis LDE program during process verification reviews completed in 1997 and 1999 and a follow-up review in 2000. In response to the 1999 review, Stennis appointed an LDE program manager and hired an independent consultant to inspect 18 critical lift cranes. Subsequent to the independent inspection and the 2000 process verification follow-up review, Stennis removed 16 of the cranes from service. Stennis returned 14 of the cranes to service after completing corrective action and elected to remove the remaining 2 cranes from service indefinitely.

## **Recommendations**

We recommended that Stennis take the necessary actions to comply with Agency safety standards for LDE operations. Our recommendations specifically addressed critical lifting operations, operator and rigger training and certifications, preventive maintenance, and inspections. We also recommended that Stennis increase Government surveillance of LDE operations and implement a system to track and resolve previously reported findings and recommendations related to crane operations and equipment deficiencies. Finally, we recommended that Stennis prohibit the use of cranes with safety deficiencies. These actions will help ensure that Stennis and its contractors do not compromise the safety of personnel and will reduce the overall risk of loss or damage to flight hardware, equipment, and facilities that are critical to NASA's propulsion programs.

## **Management's Response and OIG Evaluation**

Stennis concurred with 13 of the recommendations and partially concurred with 3 recommendations for which it proposed alternative corrective actions. Pending receipt of additional information, we consider management's planned actions responsive for all 16 recommendations. The corrective actions should result in the LDE program at Stennis

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<sup>4</sup> NASA is revising NSS/GO-1740.9B and will finalize the revised document as NASA Standard 8719.9.

being operated in a safe manner and in compliance with Agency standards. We have requested that Stennis provide us with additional documentation regarding the proposed corrective actions including additional details and planned completion dates.

Details on the status of the recommendations are in the recommendations section of the report.

**[original signed by]**

Roberta L. Gross

Enclosure

Final Report on Audit of Safety of Lifting Devices and Equipment at Stennis Space Center

W

September 28, 2001

TO: AA/Acting Director, John C. Stennis Space Center  
Q/Associate Administrator for Safety and Mission Assurance

FROM: W/Assistant Inspector General for Audits

SUBJECT: Final Report on Safety of Lifting Devices and Equipment at Stennis Space Center  
Assignment Number A-00-048-00  
Report Number IG-01-042

Enclosed please find the subject final report. Please refer to the Executive Summary for the overall audit results. Our evaluation of your response is incorporated into the body of the report. Pending receipt of additional information, we consider management's proposed actions responsive for each of the report recommendations. We request that management provide additional comments and planned completion dates for each recommendation by November 27, 2001. The recommendations will remain open for reporting purposes until corrective actions are complete. Please notify us when actions have been completed on the recommendations, including the extent of testing performed to ensure corrective actions are effective. The final report distribution is in Appendix E.

We appreciate the courtesies extended to the audit staff. If you have questions concerning the report, please contact Mr. Kevin Carson, Deputy Assistant Inspector General for Audits, at (301) 286-0498, or Ms. Sandy Massey, Program Director, Safety and Technology Audits, at (321) 867-4057.

**[original signed by]**

Alan J. Lamoreaux

Enclosure

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**SAFETY OF LIFTING DEVICES  
AND EQUIPMENT AT STENNIS SPACE CENTER**

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# NASA Office of Inspector General

IG-01-042  
A-00-48-00

September 28, 2001

## Safety of Lifting Devices and Equipment at Stennis Space Center

### Executive Summary

**Background.** Three major contractors at Stennis operate and/or maintain LDE for NASA. Mississippi Space Services (MSS)<sup>5</sup> is the Center's facility operating services contractor and has responsibility for the inspection and maintenance of all LDE on site. MSS also operates some LDE and is responsible for training and certifying all LDE operators. Lockheed Martin Space Operations-Stennis Programs (Lockheed-Martin) is the test and technical support services contractor that performs lifts of experimental engines and commercial space flight hardware to support operational testing. The Boeing Company's-Rocketdyne Propulsion and Power (Boeing) is the propulsion test contractor responsible for lifting, testing, and certifying Space Shuttle main engines for flight.

The NSS/GO 1740.9B contains the minimum safety requirements for the design, testing, inspection, personnel certification, maintenance, and use of LDE at NASA Centers. Compliance with NSS/GO 1740.9B safety requirements is mandatory for all NASA-owned and contractor-supplied equipment used in support of Agency operations at NASA installations. Center safety organizations are responsible for implementing and enforcing the standard.

**Objectives.** The overall audit objective was to determine whether Stennis and its contractors properly managed the safety of the LDE program. Specifically, we determined whether:

- Stennis safely performed critical lifts,
- crane operators were properly trained and certified,
- personnel operated cranes in a safe manner,
- MSS complied with maintenance requirements, and
- MSS performed adequate wire rope<sup>6</sup> inspections.

Appendix A contains further details on the audit objectives, scope, and methodology.

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<sup>5</sup> MSS is a joint venture of Computer Sciences Corporation and the IT Group, Inc.

<sup>6</sup> A wire rope is a number of multi-wired strands that are wrapped around a core member. LDE primarily rely on wire ropes to lift and suspend their loads; thus, the reliability of wire ropes is critical to successful lifts. If the strength of a wire rope is compromised, safety of the lift is also compromised.

**Results of Audit.** Stennis and its three major contractors did not properly manage LDE program safety. Specifically, (1) Stennis did not safely perform critical lifts (Finding A), (2) operators and riggers were not properly trained and certified (Finding B), (3) operators used cranes with safety deficiencies (Finding C), (4) crane maintenance was inadequate (Finding D), and (5) wire rope inspections were inadequate (Finding E). Stennis had been advised of many of these conditions in mishap reports, independent inspections, and internal assessments; yet, significant deficiencies in LDE management continued to exist. As a result, Stennis removed 16 critical lift cranes from service during 1999-2000. During that same period, Stennis also reported two lifting mishaps that resulted in equipment and facility damages with estimated costs of more than \$550,000.

Stennis made some improvements in LDE program safety in 2000. Specifically, the Center designated an LDE program manager, drafted an LDE program plan, and made needed repairs on some of its cranes. Despite those positive steps, the LDE program requires additional improvements. Unless Stennis makes additional improvements, the potential exists for harm to personnel and assets that are essential to NASA's space propulsion program and for future monetary losses.

**Recommendations.** We recommended that Stennis take the necessary actions to comply with Agency safety standards for critical lifting operations, operator and rigger training and certifications, maintenance, and inspections. Stennis should also revise its safety procedures and guidelines to include requirements for critical lifting operations that are unique to the Center. In addition, management should request increased Government surveillance of crane operations and implement a system to track and resolve previously reported findings and recommendations related to crane operations and equipment deficiencies. Finally, Stennis should prohibit the use of cranes with safety deficiencies.

**Management's Response.** Management concurred or partially concurred with the report's 16 recommendations. Management proposed alternative corrective actions for those recommendations for which it partially concurred. Management's planned actions for all the recommendations are responsive. We request additional information on the proposed corrective actions, including additional details and planned completion dates (see the respective recommendations in the Findings section of the report). The complete text of the response is in Appendix D.

## Introduction

The NASA Office of S&MA, located at Headquarters, performs process verification reviews at each Center on a cyclical basis. The purpose of the reviews is to assess the effectiveness and efficiency of S&MA processes and management practices implemented at each Center. The Office of S&MA determines the stability and capability of each Center's safety, reliability, and quality assurance functions based on the results of the process verification reviews.

NASA S&MA officials performed process verification reviews at Stennis in 1997 and 1999 and performed a follow-up review in 2000. The reports contained recurring findings regarding LDE. Appendix B summarizes the results of the three reviews.

As a result of the 1999 process verification review, Stennis appointed a safety official as the LDE program manager.<sup>7</sup> To get an overview of the status of all LDE, the program manager contracted with the North American Crane Bureau (NACB) to perform an inspection of 18 cranes<sup>8</sup> (of which 16 were classified as critical lift) for compliance with general industry standards. The LDE program manager and an MSS safety official (concurrent with the NACB) inspected the same 18 cranes for compliance with NASA safety standards. In May 2000, both the NACB and the LDE program manager issued reports detailing the inspection results. Appendix C summarizes the NACB's findings.

The Stennis LDE program manager's May 2000 inspection report stated that none of the 18 inspected cranes complied with industry standards or NSS/GO-1740.9B. The report cited multiple deficiencies across the Center including inadequate maintenance, lack of documentation, and failure to establish and maintain a system for supporting LDE. The report concluded that, "some of the equipment inspected indicates the potential for catastrophic failures that could dramatically impact current and future test programs."

In June 2000, the NASA S&MA Office conducted a follow-up review and again reported serious examples of safety noncompliance and management shortcomings with LDE. As a result, Stennis removed the 16 critical lift cranes from service. Stennis subsequently completed corrective actions on 14 cranes and returned them to service. There was no current program requirement for the remaining two cranes. Stennis continues to address other concerns identified by S&MA officials in the process verification reviews.

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<sup>7</sup> In July 2000, Stennis reassigned the LDE program manager responsibility to the Center Operations Directorate.

<sup>8</sup> The 18 cranes selected for review represented about 20 percent of the total LDE inventory at Stennis.

## Findings and Recommendations

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### Finding A. Critical Lift Safety

Lockheed-Martin, MSS, and Boeing did not safely perform critical lifts. Specifically, contractors routinely conducted critical lifts using noncritical lift procedures. In addition, Stennis had not completed hazard analyses and markings for its critical lift cranes or its inventory of slings.<sup>9</sup> Critical lifts were unsafe because Stennis had not (1) complied with the critical lift requirements of NSS/GO-1740.9B, (2) established critical lift requirements for its Center-unique lifting operations, or (3) provided adequate safety surveillance for critical lifts. As a result, Stennis and its contractors compromised personnel safety, destroyed Government property, and increased the overall risk of loss or damage to equipment and facilities.

#### *Safety Requirements for Performing Critical Lifts*

**NASA Requirements.** NSS/GO-1740.9B, paragraph 101(c)(1), describes critical lifts as those that are:

... special, high dollar items, such as spacecraft, one-of-a-kind articles, or major facility components, etc., whose loss would have serious programmatic impact. Critical lifts also include operations with special personnel and equipment safety concerns beyond normal lifting hazards. Each installation or program shall develop a process to identify critical lifting operations and lifting devices/equipment that must meet critical lift requirements. The results of the process shall be documented and approved, as a minimum, by the installation NASA Safety Director. In addition, specific written procedures shall be prepared and followed for all critical lifts, and individuals with a designated safety responsibility (NASA or Contractor) shall be present to monitor critical lift operations for compliance with this document.

**Stennis Requirements.** Stennis Procedures and Guidelines (SPG) 8715.1, "Stennis Space Center Safety and Health Procedures and Guidelines," January 27, 1998, establishes procedures and guidelines for all NASA operations and basic safety requirements for Stennis contractors. The SPG states that Stennis lifting operations are often one-of-a-kind and special and involve high-dollar items that contain hazardous materials or have special safety requirements.

#### *Contractor Performance of Critical Lifts*

Lockheed-Martin, MSS, and Boeing routinely performed lifts of personnel and assets requiring special lifting procedures. However, the contractors did not follow safety requirements designed to ensure that critical and/or hazardous lifting operations were performed in the safest possible manner.

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<sup>9</sup> A sling is a device used to securely hold the object to be hoisted. Slings can be constructed of wire rope, alloy steel chain, metal mesh, or natural or synthetic fiber.

**Lockheed-Martin.** Lockheed-Martin may have avoided a serious mishap that resulted in property damage and equipment loss had it complied with NASA's critical lift requirements. On November 5, 2000, Lockheed-Martin used the main derrick to raise a man-lift<sup>10</sup> from the eleventh to the sixteenth level of the B-Test Stand.<sup>11</sup> Lockheed-Martin operated the crane and rigged the man-lift. According to the mishap investigation team, the rigging failed because Lockheed-Martin used undersized slings and an improper rigging configuration, and as a result, the man-lift fell about 80 feet to the sixth level. Lockheed-Martin had successfully lifted the man-lift the day before the mishap and twice the day of the mishap using the same improper slings and configuration. Each of those lifts had an extremely high risk of catastrophic failure and potential for loss of life and property.

The man-lift, which will cost NASA about \$130,000 to replace, was completely destroyed, and the test stand sustained an estimated \$40,000 in damage. NASA incurred additional costs of about \$33,000 for other incidental expenses such as environmental cleanup, removal of the destroyed man-lift, and minor repairs to a damaged Government vehicle.<sup>12</sup> Figures 1 and 2 show the destroyed man-lift on the sixth level of the test stand.



**Figure 1. View of destroyed man-lift from the sixth level**



**Figure 2. Overhead view of destroyed man-lift**

Although the mishap caused no personnel injuries, the risk of injury or death was high. Only minutes before the mishap, three employees were in the area where the man-lift landed. An investigation team recommended that Stennis review its lifting program and equipment for compliance with the NSS/GO and SPG and coordinate lifts with respective safety offices. The mishap clearly shows the importance of properly classifying critical lifts in accordance with safety standards. Lockheed-Martin may have prevented the mishap if the company had complied with NASA's critical lift requirements.

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<sup>10</sup> A man-lift is a type of mobile equipment designed to lift personnel to work on elevated structures and equipment.

<sup>11</sup> The B-Test Stand is a 17-story structure where propulsion systems such as rocket engines are mounted for static testing.

<sup>12</sup> Stennis requested that Lockheed-Martin reimburse NASA approximately \$132,000 for mishap damages, to include market value for the man-lift, rental costs for a temporary man-lift, test stand damages, and incidental costs such as environmental clean up and removal of debris.

**MSS.** MSS also did not properly classify critical lifts or follow NASA or MSS procedures when those lifts met the NSS/GO critical lift requirements. For example, on November 2, 2000, an operator lifted workers on the B-Test Stand using a mobile crane with an attached personnel basket. Although NSS/GO-1740.9B and MSS S&MA instructions require contractors to perform personnel lifts using critical lift procedures, MSS did not properly classify the lift as critical. MSS also did not prepare specific written lift procedures or require monitoring of lifts by NASA or contractor safety personnel. Although MSS was aware of the NASA requirements and had established internal procedures, it did not properly classify or perform personnel lifts.

**Boeing.** Boeing did not follow required safety procedures for its critical lifts. From September 1, 2000, through February 28, 2001, Boeing classified 26 Space Shuttle main engines and/or engine component lifts as critical and used a qualified move director<sup>13</sup> or move conductor<sup>14</sup> when transporting and lifting engines or engine components. The NSS/GO requires that designated safety representatives be present during critical lifts or that the contractor receives NASA approval, in the form of a waiver, for an exception to this practice. Generally, neither NASA nor Boeing safety personnel were present for these lifts. Further, the move directors and conductors were not safety representatives, although they had received safety-related training. Boeing also had not submitted a waiver to obtain the Agency's approval for deviation of the requirement to have safety representatives present. Consequently, NASA had no assurance that Boeing accomplished the engine lifts in the safest possible manner.

### ***Hazard Analyses, Special Markings, and Inventories for Critical Lift Equipment***

Stennis did not comply with the NSS/GO or the SPG requirements for hazard analyses,<sup>15</sup> special markings, and inventories for critical lift equipment. The NACB, NASA Office of S&MA, and the 2000 mishap investigation team each addressed noncompliance with at least one of those requirements. However, as of June 2001, Stennis had not completed hazard analyses or markings for its critical lift cranes or its inventory of slings.

**Hazard Analyses.** Stennis did not complete the required hazard analyses and the failure mode and effects analyses (FMEA),<sup>16</sup> as applicable, for its critical lift cranes. Therefore, Stennis accepted uncalculated risks when performing critical lifts that could have caused harm to personnel and mission-critical programs.

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<sup>13</sup> A move director is a contractor employee who has ultimate responsibility for overseeing Space Shuttle main engine lifting and transporting operations.

<sup>14</sup> A move conductor is a contractor employee who has ultimate responsibility for overseeing transport and lifting operations for certain Space Shuttle main engine components (that is, nozzles and pump assemblies.)

<sup>15</sup> A hazard analysis is the identification and evaluation of potential and existing hazards and the recommended mitigation for the hazardous sources identified.

<sup>16</sup> An FMEA is a systematic, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of the modes of failure. FMEA's are a part of risk analyses; however, a hazard analysis does not have to include an FMEA to be complete.



NSS/GO-1740.9B and SPG 8715.1 require a hazard analysis for all critical lift cranes to identify potential sources of danger and recommend appropriate resolution. In addition, a system of risk acceptance is required for hazards that cannot be eliminated. Stennis must perform and document a hazard analysis as part of the initial crane certification process and update the analysis to reflect changes in operation and/or crane configuration. Cranes used to lift personnel require both a hazard analysis and an FMEA.

In June 1999, a mishap occurred at the B-Test Stand when Boeing lifted a commercial engine using the main derrick. Stennis' mishap investigation team issued a written report on the mishap to Stennis management in September 1999. The mishap report identified that Stennis had not performed a design hazard analysis on the derrick modifications completed in 1993/94. The team recommended that Stennis perform a hazard analysis on the entire derrick system. Stennis may have identified and mitigated the risks associated with the mishap if it had performed the required hazard analysis.

In 2000, two NASA internal reports addressed the need for hazard analyses. Specifically, in May, the Stennis S&MA Office reported there were no hazard analyses for the critical lift cranes.<sup>17</sup> In June, the NASA Headquarters S&MA Office recommended that Stennis perform a hazard analysis prior to any critical lift operation.<sup>18</sup> As of May 2001, Stennis still had not performed the hazard analyses and FMEA on critical lift cranes as required by NSS/GO-1740.9B and SPG 8715.1.

**Critical Lift Markings.** In May 2000, both the NACB and Stennis S&MA Office provided reports to Stennis management that identified Stennis' noncompliance with NSS/GO-1740.9B and SPG 8715.1 regarding crane markings for load bearing capability, warnings, and critical lift designation. The NSS/GO and SPG require Stennis to conspicuously mark cranes so that they are readily identified for critical lifts.

We observed critical lift cranes that were not properly marked. Without proper markings, crane operators and safety personnel could not be assured that equipment was inspected, tested, and configured to perform critical lift operations. Use of improperly marked and undesignated cranes to perform critical lifts could result in operators using under-rated or substandard cranes to perform critical operations that could, upon failure, harm personnel or damage assets, equipment, or facilities.

**LDE Inventory.** The NASA Headquarters Office of S&MA reported in its 1997 and 1999 process verification reviews and its 2000 follow-up process verification review that Stennis did not maintain its LDE inventory.<sup>19</sup> The reports showed that the NASA S&MA Office provided

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<sup>17</sup> The Stennis S&MA Office issued a report "Initial Inspection of Critical Lifting Devices at Stennis Space Center," on May 25, 2000.

<sup>18</sup> The NASA Headquarters S&MA Office provided Stennis its "Final Report - Process Verification Follow-up at Stennis Space Center June 5-9, 2000," on June 30, 2000.

<sup>19</sup> The LDE inventory includes lifting equipment and all types of slings used to perform both critical and noncritical lifts.

Stennis funding to complete an inventory in 1993, but due to a lack of resources, the Center was unable to keep the inventory current.

Stennis updated its crane inventory in 2000; however, the inventory did not include slings. Therefore, the Center was not assured that its slings had the necessary design features, maintenance, inspection, and testing required for critical lift certification as required by NSS/GO-1740.9B.

Stennis' 2000 aerial man-lift mishap report stated that Lockheed-Martin used slings that did not conform to the load rating requirements of NSS/GO-1740.9B and SPG 8715.1 and that were undersized for the lift. Had Stennis inventoried and properly documented its rigging equipment, the slings used in the mishap would have been load tested<sup>20</sup> and marked with the load test value as prescribed by the NSS/GO and SPG. The synthetic slings used in the mishap were marked with the manufacturer's load rating. However, the load test value assigned to the slings should have been reduced by 50 percent.<sup>21</sup> Lockheed-Martin did not perform a load test with the slings and, as a result, the slings did not reflect the reduced lifting capacity. Had Stennis maintained its LDE inventory and tested and marked the slings with the prescribed load rating, rigging personnel may have selected proper slings for the lift.

### ***Agency Requirements and Oversight for Critical Lift Operations***

**Stennis-Unique Lifting Requirements.** Stennis had not established critical lift policies, as required by NSS/GO, to better define and identify its Center-unique lifting operations. Therefore, contractors were not performing critical lifts in the safest possible manner. Stennis' 2000 aerial manlift mishap investigation team also concluded that the NSS/GO critical lift definition did not address all items that the team deemed critical, such as items valued at more than \$25,000 or lifts performed above critical infrastructure. We agree that Stennis needs to broaden the generic Agencywide definition of critical lift by updating SPG 8715.1 to specifically address critical lifting operations that are unique to the Center.

**Stennis' Surveillance of Lifting Operations.** Consistent with the Agency's overall safety policy, Stennis transitioned from oversight to insight<sup>22</sup> as a means to ensure the safety of NASA's programs. As a result, Stennis S&MA officials performed fewer mandatory inspections and limited surveillance to high-risk safety areas. For example, Defense Contract Management Agency (DCMA)<sup>23</sup> officials informed us that Stennis removed the mandatory

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<sup>20</sup> NSS/GO-1740.9B requires that new LDE and modified/altered/extensively repaired LDE be load tested prior to first use with a dummy load that exceeds the rated capacity of the crane by specified percentages. The NSS/GO also requires periodic rated load tests using a dummy load equal to the LDE's rated capacity.

<sup>21</sup> NSS/GO-1740.9B and SPG 8715.1 require that ratings for synthetic rope slings be reduced by 50 percent of the manufacturer's load rating and permanently marked with the reduced rating based on load test results.

<sup>22</sup> Insight is a surveillance mode requiring only the monitoring of customer-identified metrics and contracted milestones. Insight is a continuum that can range from low intensity, such as reviewing quarterly reports, to high intensity, such as performing surveys and reviews.

<sup>23</sup> Stennis delegated safety surveillance for the Lockheed-Martin, MSS, and Boeing contracts to the DCMA.

inspection requirements for Boeing's engine lifts, thus eliminating DCMA oversight of lifting operations under the Boeing contract.

Mishap investigations, independent assessments such as the NACB crane inspection, and functional reviews like the NASA Headquarters S&MA Office's process verification reviews, are key sources of data for establishing a method of insight. Although Stennis received various reports from these sources that identified serious LDE deficiencies, Center safety officials did not increase the risk or the level of surveillance associated with the Center's lifting operations.

### ***Conclusion on Critical Lift Operations***

Although the three Stennis contractors were aware of the NSS/GO requirements, they did not properly classify and conduct critical lifts in accordance with the NASA standards. Further, Stennis did not provide adequate safety oversight necessary to identify and correct the deficiencies in the Center's critical lift operations. In addition, Stennis did not comply with requirements for hazard analyses, critical lift markings, and a complete LDE inventory even though multiple reports addressed these deficiencies. As a result, Stennis and its contractors compromised the safety of personnel, destroyed Government property, and increased the overall risk of loss or damage to flight hardware, equipment, and facilities when performing critical lifts.

## **Recommendations, Management's Response, and Evaluation of Response**

**The Director, John C. Stennis Space Center, should:**

**1. Direct all Stennis contractors to conduct critical lifts in accordance with NSS/GO-1740.9B and SPG 8715.1.**

**Management Response.** Concur. All contractors shall be directed to conduct critical lifts in accordance with NSS/GO 1740.9 and the Stennis LDE Management Plan.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. However, we ask that Stennis provide additional details describing how it will direct the contractors to perform critical lifts in accordance with Agency and Center standards and to provide planned completion dates. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**2. Direct the Manager, Safety and Mission Assurance and the LDE Program Manager to perform hazard analyses, mark cranes, and maintain an LDE inventory as required by NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Partially Concur. Stennis will require hazard analyses for new LDE and for procurement of new cranes. Contracts for new equipment will require that

suppliers provide hazard analyses. Hazard analyses are primarily utilized in the design phase. Because Stennis has adequate historical data on its existing critical lift cranes, the most appropriate and value-added approach for those cranes is to perform risk evaluations in lieu of hazard analyses. The LDE Management Plan requires capacity markings for all cranes and conspicuous markings for all critical lift cranes. A Stennis work order will be prepared to ensure all cranes are marked as required. An inventory of all lifting devices is currently maintained in the Facility Operations Support Contractor (FOSC) Computerized Maintenance Management System (CMMS). Although an inventory of slings is not required, all contractors have been tasked to maintain an inventory of their rigging gear.

**Evaluation of Management's Response.** Management's planned actions are conditionally responsive to the recommendation. However, Stennis did not address obtaining waivers from the hazard analyses requirement for the existing cranes. A waiver may be authorized when it is adequately justified and approved at the appropriate management level. Stennis informed us that it plans to request waivers for the existing equipment requiring hazard analyses and that the Center Director would be the approving authority for those waivers. If the Center plans to obtain properly approved waivers, then management's response would meet the intent of the recommendation. As for recommendation 1, we ask management to provide additional details describing how critical lift cranes will be marked and the planned completion date for marking all cranes. Stennis should also needs provide additional details describing how the contractors will maintain the rigging equipment inventory, including a planned completion date for the inventory. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

### **3. Revise SPG 8715.1 to identify Stennis-unique critical lift requirements.**

**Management Response.** Concur. The Stennis LDE Management Plan has been modified to define unique, programmatic critical lifts. Upon final approval, the plan will replace the current chapter on LDE in SPG 8715.1.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. However, we ask that Stennis provide its definition of unique, programmatic critical lifts and the planned completion date for approval of the Center's LDE Management Plan and its incorporation into SPG 8715.1. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

### **4. Increase Government surveillance of critical lifting operations to ensure they comply with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management Response.** Concur. The Stennis S&MA office has been tasked to prepare a surveillance plan that will ensure compliance with all requirements of NSS/GO 1740.9 and the Stennis LDE Management Plan. The surveillance plan will address training and certification of operators, maintenance of equipment, procurement of new equipment, and surveillance of lifting operations.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. We ask that Stennis provide a planned completion date for implementing the surveillance plan. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

## **Finding B. Training and Certifying Operators and Riggers**

MSS, Boeing, and Lockheed-Martin did not train and certify crane operators and riggers in accordance with NASA and Stennis standards. Noncompliance with Agency requirements occurred because (1) MSS did not properly administer a Center-wide personnel training and certification program, and (2) Stennis did not provide adequate surveillance or correct training and certification deficiencies previously reported. Consequently, the three contractors routinely performed lifts without properly trained and certified operators and riggers. The lack of adequate training contributed to two major mishaps costing NASA more than \$550,000.

### ***Training and Certification Requirements***

**NASA Requirements.** NSS/GO-1740.9B requires NASA Centers to establish training, testing, and licensing programs for crane operators and riggers. Additionally, critical lift operators must demonstrate proficiency for initial certification, and their licenses must identify each crane they are authorized to operate.

**Stennis Requirements.** SPG 8715.1, Section I.1.4, "Safety and Health Training, Education and Certification," requires certification of all Government and contractor personnel who perform hazardous and/or critical operations. Personnel must have the knowledge, skill, judgment, and physical ability to perform in a safe, qualified manner. Requirements for certified personnel<sup>24</sup> include (1) physical examinations, (2) on-the-job and classroom safety training, and (3) written and operational qualification testing. MSS is responsible for training and certifying all LDE operators.

### ***Contractor Compliance with Training and Certification Requirements***

We reviewed training and certification records for MSS, Boeing, and Lockheed-Martin crane operators and riggers and determined they did not comply with Agency and contractor certification requirements.

**MSS Operator Qualifications.** Consistent with NASA standards, MSS Safety and Health Requirement 007, "Crane Operator Proficiency and Rigging and Inspection Proficiency," requires that operators be issued certificates that identify the cranes the operators are qualified to operate. However, none of 13 MSS operators had crane-specific certifications. Rather, operators were certified for crane categories such as

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<sup>24</sup> MSS also established requirements for its crane operators. The MSS Safety Office Desk Guide, number 18-35-005, "Employee Certification," identifies special skills and/or critical operations for which personnel must be certified. The Guide requires personnel performing lifting, rigging, derrick, and/or man-lift operations to be trained and certified.

mobile or overhead cranes.<sup>25</sup> In addition, MSS did not require operators to demonstrate proficiency on specific critical lift cranes. The operators, therefore, did not meet Agency or internal certification requirements.

Only three of the nine MSS employees who performed crane inspections were certified crane operators. Inspectors must operate a crane to perform a proper inspection and, therefore, must be operator certified. We observed two of the six noncertified inspectors operating cranes while performing crane maintenance and inspections. NASA, Stennis, and MSS safety standards clearly state that only certified personnel are authorized to operate cranes.

**MSS Training and Examination.** The MSS Safety Office developed and conducted general classroom training for mobile and overhead crane operators; however, the training was not crane-specific. MSS also did not provide on-the-job training.

MSS requires operators to pass a written examination upon completion of training. We attended a course and observed operators using course materials to complete the examination. Although some materials such as charts for calculating load limits at various angles were needed to answer some questions, operators should have answered other questions based on knowledge and experience. Allowing participants to use handout materials defeated the purpose of the test, which was to determine whether operators had the knowledge and skill to safely operate a crane.

We reviewed eight tests taken by certified operators. Although the MSS instructor did not grade the tests, he passed each operator. We subsequently graded the tests and found that four operators failed by scoring less than the minimum required passing score of 85 percent.

Crane operators also had to complete performance tests. Similar to the classroom training, MSS conducted overhead crane performance tests using only two cranes rather than the specific crane the operator would operate.

**Boeing Operator and Rigger Qualifications.** Boeing operators and riggers did not comply with Agency certification requirements. Boeing trained and certified its operators in accordance with a Rocketdyne-Stennis Safety Manual,<sup>26</sup> dated July 1998. The manual required operators to train, witness and practice lifts, and pass a qualification test. Boeing did not require operators to pass physical examinations prior to certification as mandated by NASA.

Boeing had 96 overhead crane operators and riggers; however, none were certified on specific cranes. Further, although 74 of the 96 operators were certified as meeting Boeing requirements, 20 did not have physical examinations. Boeing considered the remaining 22 operators to be qualified but not certified.

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<sup>25</sup> In May 2000, the Stennis LDE program manager reported that basic operator training did not comply with industry standards because certifications were general category rather than crane-specific.

<sup>26</sup> In 1996 Boeing acquired Rocketdyne (previously a Division of Rockwell International Corporation). Boeing has an updated training program in draft and established a new Web-based examination for operators in September 1999.

**1999 Lifting Mishap.** On June 23, 1999, a mishap<sup>27</sup> occurred during a Boeing lift of a commercial engine using the main 200-ton derrick.<sup>28</sup> Support personnel noticed vibration and noise from the derrick and evacuated the area before the roller bracket, shaft, and debris fell to the ground. The mishap resulted in more than \$350,000 in damages.

In September 1999, the Stennis mishap investigation team reported that inadequate training and a lack of experience caused the lifting mishap. Specifically, the operators and riggers had only about 2 hours of on-the-job training and had performed only one critical lift under qualified operator supervision. The lift's draw-works observer<sup>29</sup> received only 1 hour of on-the-job training. After the mishap, Stennis assigned all derrick operations to Lockheed-Martin.

**Lockheed-Martin Operator and Rigger Qualifications.** Like MSS and Boeing, Lockheed-Martin had its own certification program. Lockheed-Martin's Personnel Certification Plan requires personnel performing critical tasks or hazardous operations to have physical examinations, on-the-job training, and certifications. Operators and riggers are recertified annually to those requirements.

Lockheed-Martin had a total of three derrick operators, 40 crane operators, and 14 riggers. We reviewed 15 derrick and crane operator certifications. All of the operators had completed physical examinations, safety overviews, and proficiency tests; however, none had crane-specific certifications as required by NASA.

**2000 Lifting Mishap.** As described in Finding A, on November 5, 2000, a man-lift fell about 80 feet from the B-Test Stand main derrick because Lockheed-Martin used improper rigging to perform the lift. The mishap resulted in a destroyed man-lift, damage to the stand, and incidental expenses totaling more than \$200,000.

Lockheed-Martin had to recertify its riggers because of training and skill deficiencies identified in the 2000 mishap investigation team's report. For the second time in 2 years, a mishap investigation team cited lack of adequate training as the major cause of a lifting mishap at Stennis.<sup>30</sup> The investigation team determined that Lockheed-Martin riggers did not possess basic rigging skills<sup>31</sup> because training and testing were inadequate. Specifically, rigger training consisted only of video examples of rigging equipment rather than detailed rigging instruction. Further, the written test was primarily true/false and did not provide a good evaluation of rigging knowledge. Lockheed-Martin suspended rigger certifications in November 2000 and

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<sup>27</sup> The mishap occurred when the main derrick's hook traveled upward until the lower sheave block contacted the upper-fixed sheave block. The main hoist pulled the two blocks together and damaged the upper block and main hoist cable and caused a roller bracket and shaft assembly to fall to the test stand.

<sup>28</sup> At Stennis, a derrick is a large fixed crane mounted near the top of the test stands.

<sup>29</sup> The draw-works observer ensures proper operation of equipment that powers the hoisting mechanism.

<sup>30</sup> Both the 1999 and 2000 mishap reports cited inadequate training as the main cause for the incidents.

<sup>31</sup> The team reported that riggers did not understand proper sling usage or how to determine proper sling size.



reactivated them in February 2001 when employees completed 16 hours of classroom and hands-on training.<sup>32</sup>

### ***Center-wide Personnel Certification Program***

The lack of a Center-wide personnel certification program has contributed to the lack of compliance with the Agency's LDE requirements. As part of its contract for Stennis' facility operating services, MSS is responsible for developing a comprehensive training program for Stennis and its contractor crane operators and riggers. MSS did not administer a program for all three contractors (MSS, Boeing, and Lockheed-Martin) operating cranes at Stennis. Rather, each of the three managed its own training program. A Center-wide training and certification program would provide consistency and compliance with NASA and Stennis certification requirements.

### ***Stennis Reliance on Contractor Mishap Investigation Board and Implementation of Corrective Actions***

Stennis relied too heavily on contractor oversight of crane operations. For example, Stennis improperly relied on contractors with potential conflicts to perform the 1999 mishap investigation. NASA Policy Directive (NPD) 8621.1G, "NASA Mishap Reporting and Investigating Policy," provides that Center Directors will appoint and approve mishap investigation officials when damages or losses are from \$250,000 to \$1 million. Mishap Investigation Boards must be NASA sponsored and consist of individuals with expertise in the area with no vested interest in the outcome. However, a NASA project manager tasked Lockheed-Martin to assemble a team<sup>33</sup> to investigate the mishap. Other Stennis contractor employees also served on the board. Even though Boeing was operating the derrick when the mishap occurred, it had representatives on the board. There was no evidence the Center Director approved the investigation team or received a copy of its final report. Our review of the 2000 man-lift mishap showed that the Center Director complied with the NPD by appointing and approving the appropriate investigation officials.

Finally, Stennis did not implement some of the board's recommendations. For example, the board recommended comprehensive training for the riggers. However, Stennis did not provide rigger training until February 2001, or after the second mishap occurred in 2000. Stennis may have avoided the 2000 mishap if it had implemented the rigger training promptly after the board's recommendation in 1999. Tracking and resolving training and certification recommendations made by both internal and external organizations will further help ensure that lifting operations are conducted in as safe a manner as possible, and by properly qualified personnel only.

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<sup>32</sup> Stennis hired an independent contractor to conduct two 16-hour rigging courses.

<sup>33</sup> The team consisted of NASA, Lockheed-Martin, Johnson Controls World Services, and Boeing representatives. The three NASA representatives on the team functioned only as advisors.

### ***Conclusion on Training and Certifying Operators and Riggers***

Properly trained and certified crane operators and riggers are the single most important factor in ensuring safe lifting operations. Training deficiencies were the main cause of the two mishaps costing NASA more than \$550,000; however, the lack of training and certification remains a significant weakness. Increased Government surveillance of contractor compliance with the training and certification requirements of NSS/GO-1740.9B and SPG 8715.1 will help ensure that only properly trained and certified operators perform lifts at Stennis. Until Stennis ensures its operators and riggers are qualified and properly certified, the Center faces risk of additional mishaps, personnel injury or death, and loss or damage to equipment and facilities essential to NASA.

### **Recommendations, Management's Response, and Evaluation of Response**

**The Director, John C. Stennis Space Center, should:**

**5. Direct MSS to establish and maintain a comprehensive training and certification program for all operators and riggers at Stennis and to ensure that certifications are in compliance with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Partially concur. Stennis is establishing a comprehensive training and certification program for all operators and riggers, which will comply with NSS/GO-1740.9 and the Stennis LDE Management Plan. Overall responsibility may be assigned to an organization other than MSS.

**Evaluation of Management's Response.** Management's planned actions are responsive to the recommendation. We ask Stennis to provide additional details describing how the training and certification program will be managed as well as a planned completion date for establishing the responsible organization. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**6. Increase Government surveillance of contractor compliance with training and certification requirements to ensure compliance with NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Concur. See the response to Recommendation 4.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. As for recommendation 4, we ask that management provide a planned completion date for implementing the surveillance plan. The recommendation is resolved, but

will remain undispositioned and open for reporting purposes until corrective actions are completed

**7. Direct the Manager, Safety and Mission Assurance, to track and resolve training and certification recommendations made by both external and internal reviews such as investigation boards, process verification reviews, or independent assessments.**

**Management's Response.** Concur. All training and certification recommendations from external and internal reviews will be addressed in the comprehensive training plan identified in Recommendation 5.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. As for recommendation 5, we ask management to provide additional details describing how the training and certification program will be managed and to provide a planned completion date for establishing the responsible organization. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

## **Finding C. Crane Operation Safety**

LDE operators routinely used cranes and derricks with safety deficiencies. Cranes were unsafe because contractor personnel did not follow established procedures for recording, reporting, and correcting crane and derrick deficiencies and disregarded previously recommended corrective actions for reporting and correcting crane deficiencies. Also, the Government lacked oversight of crane operations. As a result, operators did not have sufficient information to assess the safety and reliability of cranes prior to operation and, in some cases, conducted operations with unsafe equipment.

### ***Requirements for Safety Inspections and Corrective Maintenance***

NSS/GO-1740.9B and SPG 8715.1 require a documentation process for crane problems and deficiencies. Contractor crane operators must perform daily equipment inspections and review previously recorded deficiencies to assess their impact on planned lifting activities. Stennis has established procedures for meeting this requirement by using crane logbooks<sup>34</sup> that are to be maintained in the operator's area of each crane. In addition, contractor crane operators must report deficiencies to their supervisor and obtain approval to continue operations. MSS is responsible for correcting hazardous conditions prior to further use of the equipment.

### ***Cranes with Safety Deficiencies***

Our review of crane logbooks showed that operators continued to use cranes and derricks with known safety deficiencies.

**Contractor Logbooks.** Boeing and Lockheed-Martin had no logbooks for overhead cranes, and MSS stopped maintaining logbooks for mobile cranes in 1999. Lockheed-Martin derrick operators maintained logbooks, but did not consistently record required data, such as the specific lift description, the device used, or corrective actions. Additionally, when MSS mobile crane operators maintained logbooks, they routinely recorded entries such as "same as above" or "same as last entry." Therefore, it was difficult for an operator to determine existing problems with a particular crane or derrick. For example, in September 1999, an operator recorded "same as above" for two entries related to a wire rope problem recorded in August 1999. However, MSS had replaced the wire rope on August 25, 1999 (prior to the September entries). Therefore, we questioned the adequacy of the pre-operational inspections of the crane's wire rope. Examples of problems we noted with operator logbooks are shown in Table 1.

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<sup>34</sup> Logbooks are used to record the results of daily operator inspections.

**Table 1.**  
**Problems Noted in Crane Operator Logbooks**

Crane Description	Job Not Listed	Noted "Same as Previous Entry"	Problems Not Fixed Promptly	Lifts Made With Problems Noted	No Evidence of Supervisory Approval to Continue Lifts	Logbook Not Current	Date of Last Recorded Lift
130-93 Mobile	X	X	X	X	X	X	11/19/99
130-101 Mobile	X	X	X	X	X	X	12/09/99
130-105 Mobile	X	Logbook weathered and illegible				X	09/22/99
130-106 Mobile	X	X	X	X	X	X	12/01/99
A-1 Derrick	N/A	N/A	N/A	N/A	N/A	N/A	06/07/00
A-2 Derrick	N/A	N/A	X	N/A	N/A	N/A	05/19/00
L92 B1/B2 Derrick	N/A	N/A	N/A	N/A	N/A	N/A	12/05/00
L91 B1/B2 Derrick	N/A	N/A	X	X	X	N/A	12/19/00
L5/L6 Overhead	X	N/A	N/A	N/A	N/A	X	03/16/00
L10/L11 Overhead	N/A	N/A	N/A	N/A	N/A	X	04/20/99

N/A – Not Applicable

Some recorded problems were recurring, long-standing conditions,<sup>35</sup> particularly on the Center's mobile cranes. Table 2 lists examples of long-standing problems and associated operator comments from mobile crane logbooks.

**Table 2.**  
**Recurring, Long-Standing Problems Recorded by Mobile Crane Operators**

Crane Number	Equipment Problem Recorded in Logbook	Period Noted	Operator Remarks Recorded Throughout Logbook
130-093	Outrigger(s) Leaking Down	7/97–11/99	"No action taken" "Leaks down bad" "Still leaks after 6 months"
130-093	Hydraulic Fluid/Oil Leaks	7/97–11/99	"Motor leaks oil bad" "No action taken" "Oil leaks everywhere" "Needs help" "Very unsafe—turned in number of times"
130-093	Cable Too Short	7/97-7/99	"Cable too short to do some jobs"
130-093	Need Boom Angle Indicator	7/97-11/99	"Boom indicator needs numbers" "Needs new one"
130-101	Hydraulic Fluid/Oil Leaks	7/97-7/99	"Oil leaks bad"
130-106	Cable Bad and Too Short	8/98-4/99	"Down to wrap and a half and smashed spot in cable" "Need new cable bad" "Need another 50-100 feet of cable" "Need cables main and jib. Has been turned in"
130-106	Cable Bad	8/99-12/99	"Bad Spot in Cable"
130-106	Brake Needs Adjusted –Whip Line Riding Up	12/98-2/99	"All this and more has been turned in"

<sup>35</sup> Operators noted many problems under the previous facilities operations contractor; however, delays in crane repairs continued to be a problem after Stennis awarded the new contract to MSS in August 1999.

**Crane Conditions for Lifts.** Operators continued lifting operations on three mobile cranes when the wire rope was too short. For example, operators reported the rope was down to a wrap-and-a-half<sup>36</sup> on critical lift crane number 130-106<sup>37</sup> as early as August 1998; however, crane operations continued until the facilities operations contractor replaced the wire rope in April 1999. In August 1999, operators again reported a problem with the wire rope on crane number 103-106, and, as before, continued using the crane until maintenance replaced the rope in May 2000. During both periods between reporting of the wire rope problems and actual wire rope replacement, operators performed numerous lifts, including lifts of rocket engines and personnel. The continued use of cranes with insufficient rope clearly violated lifting standards and could have resulted in loss of critical flight hardware or harm to personnel.

### ***Procedures for Reporting Deficiencies***

Derrick operators did not follow Stennis procedures for recording or notifying their supervisors of problems encountered on the derricks. An operator informed us that Lockheed-Martin orally communicated problems to MSS maintenance for either resolution or approval to continue operations. The MSS maintenance supervisor confirmed that deficiencies were sometimes reported orally. Occasionally, operators documented that either a supervisor or MSS representative was notified and approved continued operations. However, we found no evidence that supervisors, maintenance crews, or safety personnel (Government or contractor) reviewed the logbooks. Review of the logbooks by these personnel would have detected that (1) operators did not follow procedures to identify, document, and report problems prior to lifting operations, (2) MSS did not resolve documented deficiencies promptly, and (3) cranes were unsafe to operate.

### ***Implementing Corrective Actions***

The 1999 mishap report identified a lack of procedures for recording and tracking deficiencies identified by operators. The report recommended replacing the existing Derrick Operations Logbook (a generic ledger) with a Derrick Operations Record to track maintenance, deficiencies, corrective actions, derrick status, and other required logbook data. As of March 2001, Stennis had not implemented the recommendation. Therefore, we could not determine whether MSS had corrected problems recorded or reported by the derrick operators.

In May 2000, the NACB found crane deficiencies throughout the Center and recommended that Stennis incorporate a detailed inspection program to assure crane operational readiness, placing special emphasis on wire rope conditions. MSS corrected many of the NACB reported deficiencies; however, several of the deficiencies were long-standing. MSS had documented procedures for performing crane inspections and specific procedures for wire rope inspections

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<sup>36</sup> The NSS/GO and SPG 8715.1 preclude operators from using cranes with less than two full wraps of rope on the hoist drum.

<sup>37</sup> Mobile crane 130-106 was classified for critical lifts; however, MSS used other mobile cranes not classified for critical lifts to perform lifts that met NSS/GO critical lift requirements.

which MSS did not always follow. In our opinion, MSS should have identified, reported, and corrected the deficiencies prior to the NACB report.

### ***Conclusion on Crane Operation Safety***

Operators continued to perform lifts when cranes were unsafe to operate. Because MSS did not record the results of inspections and maintenance in crane logbooks, operators did not have sufficient information to assess cranes for lift safety and reliability. Available logbooks showed that many cranes had known deficiencies, some for prolonged periods. Although performing pre-operational safety inspections and maintaining logbooks is key to ensuring safe operation of cranes and associated equipment, LDE operators did not perform those tasks. Further, had Stennis provided adequate safety oversight of crane operations, many of the problems identified by the 1999 mishap investigation team, the NACB, and this audit could have been avoided.

## **Recommendations, Management's Response, and Evaluation of Response**

**The Director, John C. Stennis Space Center, should:**

**8. Direct contractor personnel, including operators, maintenance and inspection crews, and supervisors, to maintain logbooks for all cranes as required by NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Partially Concur. The Stennis LDE Management Plan has incorporated a requirement for operators' daily inspection checklists, in lieu of a logbook, for all cranes. The checklists will be maintained until all open corrective actions are closed. If no discrepancies are noted, the checklists will be deleted after 30 days. Permanent records regarding LDE corrective maintenance will be maintained in the FOSC CMMS system.

**Evaluation of Management's Response.** Management's planned actions are responsive to the recommendation. We ask Stennis to provide a planned completion date for implementing the daily inspection checklist and describe how it will monitor the checklist for completion of corrective actions. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**9. Implement promptly the previously recommended corrective actions for reporting and correcting crane and derrick deficiencies.**

**Management's Response.** Concur. The reporting and correcting of crane and derrick deficiencies will be tracked by means of the checklists described in recommendation 8. Permanent records regarding LDE corrective maintenance will be maintained in the FOSC CMMS system.

**Evaluation of Management's Response.** Management's planned actions are conditionally responsive to the recommendation. However, Stennis did not state how previously recommended corrective actions will be addressed on the operators' daily checklists. If management plans to incorporate previously recommended corrective actions on the initial daily operator checklist and complete the appropriate maintenance, then management's actions would meet the intent of the recommendation. In addition, Stennis should provide us a planned completion date for implementing the process of preparing operator checklists. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**10. Prohibit the use of cranes with known hazardous deficiencies as required by NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Concur. Contractors shall be directed to tag out cranes with known hazardous deficiencies.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. We ask that Stennis provide additional details describing how it will direct contractors to tag out cranes when necessary and to provide a planned completion date. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**11. Increase Government surveillance of contractor compliance with crane operation safety requirements and supporting documentation in accordance with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response.** Concur. See response to Recommendation 4.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. As for recommendation 4, management should provide us a planned completion date for implementing the surveillance plan. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.



## **Finding D. Preventive Maintenance for Cranes**

MSS did not perform adequate preventive maintenance (PM)<sup>38</sup> on cranes located at Stennis. Specifically, MSS did not schedule, perform, or document PM as required by Agency standards. PM deficiencies occurred because (1) MSS experienced problems with its computerized maintenance system and (2) neither Stennis nor MSS provided adequate oversight or implemented recommended corrective actions for maintenance deficiencies. As a result, contractors performed lifts with some cranes that were unsafe to operate.

### ***Requirements for Crane Preventive Maintenance Program***

**NASA Requirements.** NSS/GO-1740.9B and SPG 8715.1 require that the Centers establish PM programs based on manufacturers' recommendations and/or experience. PM programs should include procedures for scheduling periodic maintenance and making needed adjustments, replacements, and repairs. In addition, the Centers must prepare maintenance records and document unsafe test and inspection discrepancies.

**Stennis Requirements.** Stennis Operating Instruction (OI) 40-01-52, "Guidelines for Process Control," requires MSS to plan and schedule maintenance using MAXIMO.<sup>39</sup> Stennis OI 40-01-015, "Administration of the Preventive Maintenance Program," requires MSS to develop and update PM schedules, maintain the MAXIMO database, generate reports, and develop and revise maintenance instructions. Stennis OI 40-01-001, "Operating Instruction for Issuance, Use and Completion of the Work Order Document within the Facilities Systems Department," provides guidance for completing work orders for PM.

### ***Compliance with Crane PM Requirements***

The MSS program for PM was inadequate. Our review of PM work orders and observations of maintenance activities showed that MSS did not schedule, perform, or document PM activities for cranes in accordance with Agency standards.

**Scheduling and Performing PM.** MSS did not schedule or perform PM as required. Specifically, MSS deferred PM for 15 of 64 work orders we reviewed, thus negating the purpose of routine maintenance. For example, for the Grove 25-ton mobile crane, we found that during an 8-month period, October 1999 through May 2000, MSS issued one work order for monthly maintenance, two work orders for quarterly maintenance, and one work order for annual maintenance. MSS completed the scheduled PM for two of the four work orders on the same day and then needlessly completed the PM for the remaining two work orders just 6 days

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<sup>38</sup> The MSS contract defines preventive maintenance as the planned, scheduled, periodic inspection, adjustment, cleaning, and lubrication of equipment and systems.

<sup>39</sup> MAXIMO is a computerized maintenance management system used to track and report all PM for Stennis structures, facilities, utilities, systems, and Government property.

later. Table 3 shows the various PM work orders scheduled and the actual maintenance performed.

**Table 3.**  
**PM Scheduled and Performed on the Grove 25-ton Mobile Crane**  
**From October 1999 Through May 2000**

Work Order Number (A)	PM Cycle (B)	Work Order Issue Date (C-- See Column E)	Work Order Comment (D)	Preventive Maintenance Completion Date (E)
6905	Quarterly	10/17/99	Deferred to work order 11275. Crane used for Shuttle support.	Completed on work order 11275 on 5/28/00
11275	Quarterly	1/16/00	None	Completed 5/28/00
21642	Annual	5/5/00	Hydraulic filter and oil changed 3 weeks prior.	Completed 5/22/00
25014	Monthly	5/18/00	Deferred to Work Order 21642.	Completed 5/22/00

From October 1999 through May 2000, MSS should have issued eight PM work orders for the Grove 25-ton crane. According to the maintenance requirements for the Grove crane, MSS should have scheduled and performed monthly, quarterly, semiannual, and/or annual PM each year. Only one type of maintenance is required each month, and MSS should not schedule or perform quarterly and annual PM in the same month. As shown in Table 3, from October 1999 through May 2000, MSS did not schedule or perform the required monthly or semiannual PM. Finally, after performing no maintenance for 7 months, MSS scheduled and performed three types of maintenance (monthly, quarterly, and annual) in May 2000 when only annual PM was necessary.

We found similar problems for two other mobile cranes. Specifically, MSS deferred scheduled monthly PM for an 8.5-ton and a 75-ton crane from November 1999 until March 2000. Consequently, MSS did not service those cranes for 4 months.

We also questioned whether MSS actually performed some PM. For example, work order 21642 (shown in Table 3) showed that MSS changed the mobile crane's hydraulic oil and filter 3 weeks prior to completing work order 21642. However, no work orders showed that MSS changed the crane's oil and filter during either April or May 2000.

MSS also did not document the use of consumable materials such as oil, hydraulic fluid, filters, and lubricants when performing PM. Of the 64 work orders we reviewed from August 1999 through September 2000, none showed requests for or use of materials. Based on MSS' accounting data, we determined that only one PM work order showed associated material costs of \$22.33. The absence of materials costs for routine maintenance indicated that MSS might not have performed some required PM tasks.

In May 2000, the NACB reported PM deficiencies to Stennis. The NACB reported numerous problems such as leaking seals and inadequate lubrication on critical lift cranes. MSS had performed maintenance and/or inspections on the same cranes in the months immediately prior to the NACB inspections. However, MSS work orders did not reflect similar problems with the same cranes during the same period.

MSS management was aware of inadequacies in its maintenance program. MSS documented problems with maintenance in its September 30, 2000, Maintenance Plan.<sup>40</sup> Specifically, the plan stated that MSS had not (1) provided adequate visibility of upcoming work requirements or (2) consistently met performance metrics for completing PM.

**PM Observations.** Our observations of PM on selected cranes also raised concerns about the adequacy of the maintenance performed. For example, on October 20, 2000, we initially planned to observe semiannual maintenance on two overhead cranes (L-19 and L-20). On that day, however, MSS performed PM only on the L-20 crane and stated that it completed PM on the L-19 crane in September. However, July 12, 2000, was the last recorded PM for the L-19 crane.

During our October 20, 2000, observation, MSS was unable to perform some required maintenance tasks such as inspecting the brakes and drive motor on the L-20 crane because the components were housed inside a sealed compartment. The work order for the L-20 crane also required changing of the gearbox lubricant. However, the maintenance crew did not change the gearbox lubricant because the crew's supervisor instructed it to change the lubricant annually instead of semiannually.

We also observed many mobile cranes with safety and maintenance deficiencies. Some of the more significant crane deficiencies included fluid leaks, badly worn tires, and cracked glass. Figures 3 and 4 show the condition of a mobile crane used almost daily at Stennis.

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<sup>40</sup> MSS prepared a maintenance plan, dated September 30, 2000, in accordance with its contract terms. According to a cover letter accompanying the plan, it was submitted in response to a pledge by the MSS Board of Directors to improve its performance on PM and corrective maintenance activities.



**Figure-3. Bald tires on a 55-ton mobile crane.**



**Figure-4. Cracked operator's cab roof glass on a 55-ton mobile crane.**

During the audit, MSS initiated corrective actions such as replacing tires and cleaning up leaking areas on some cranes.

**MSS PM Documentation.** MSS did not document PM work orders in accordance with Stennis OI 40-01-001. A total of 38 (59 percent) of 64 work orders reviewed did not show the actual labor hours charged or identify the personnel performing the PM tasks. Twenty-two (34 percent) of the 64 work orders did not show the PM tasks to be performed. Forty-two (66 percent) of the work orders did not contain evidence of any type of supervisory review.

### ***MSS Transition to an Upgraded Maintenance Management System***

MSS primarily attributed PM scheduling problems to its transition to an upgraded version of the MAXIMO maintenance management system. When MSS brought the new version on-line, MAXIMO erratically scheduled required PM. MSS subsequently revised the PM schedule within MAXIMO to distribute PM more evenly.

Work orders also did not include all required PM tasks because MSS did not import equipment specification tables<sup>41</sup> into the upgraded version of MAXIMO. After MSS reconstructed the tables, work orders included more of the appropriate PM requirements. However, the work orders did not include the level of detail as those issued prior to the MAXIMO upgrade. For example, quarterly PM for a 4.5-ton mobile crane previously required 41 tasks. The quarterly PM work orders for a 4.5-ton mobile crane in the new version of MAXIMO contained only seven required tasks.

According to MSS, managing maintenance requirements became more difficult as the number of cranes increased. To alleviate the problem, MSS developed maintenance

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<sup>41</sup> Equipment specification tables contain relevant maintenance data such as minimum wire rope diameters, fluid specifications, lubrication points, and scheduled maintenance intervals and tasks.

instructions for the various crane categories (bridge, derrick, mobile). However, because the maintenance instructions were not crane specific, all PM tasks were not applicable to the cranes in a given category.

### ***Government and Contractor Oversight of the Preventive Maintenance Program***

**Government Oversight.** The DCMA letter of delegation for the MSS contract requires audit coverage necessary to assure compliance with contractor quality and safety requirements and mandatory surveillance for repair and testing of safety critical equipment, including cranes. The DCMA, however, did not adequately provide surveillance of maintenance and testing. According to monthly status reports, DCMA representatives performed minimal surveillance of PM. Specifically, reports prepared from December 1999 through August 2000 identified that only 1 out of 670 DCMA surveillance observations related to crane maintenance. Based on maintenance deficiencies noted in the May 2000 NACB and Stennis internal inspection reports, we would have expected significantly more maintenance observations by the DCMA during the 9-month period. Due to the DCMA's failure to report PM deficiencies, we question the adequacy of its surveillance.

**MSS Oversight.** The MSS Maintenance Plan provides for quality reviews to include reviewing (1) work orders, (2) required PM compared to actually performed, and (3) documented discrepancies and findings. However, MSS had not performed any quality reviews of crane maintenance. Further, the only evidence of MSS safety reviews we found was for load tests.

### ***Center Implementation of Corrective Actions***

Stennis received reports that identified PM deficiencies from the NASA Office of S&MA, the NACB, and its own staff. The internal Stennis report further addressed MSS personnel's lack of knowledge of required PM tasks and stated that PM documentation was incomplete. Despite the many deficiencies identified in each of the reports, the Stennis S&MA office did not increase its oversight or direct the DCMA to increase its surveillance of the MSS PM program. Further, the Stennis S&MA office did not require MSS to address or correct PM deficiencies until 16 cranes were taken out of service in June 2000.

The Center's lack of oversight was also demonstrated by its failure to implement corrective actions from the NASA Lessons Learned Information System. A 1997 entry in that system reported a mishap caused by a mobile crane's leaking outrigger. The leak was attributed to failure to perform scheduled PM. Crane operators continued to record similar problems in crane logbooks through December 1999. However, because MSS operators stopped maintaining logbooks in 1999, we could not determine whether similar problems continued or MSS initiated corrective actions.

## ***Conclusions on Preventive Maintenance***

The keys to a successful PM program are scheduling and execution. A successful PM program focuses on cleaning, lubrication, correcting deficiencies, replacing minor components, and safety. Complete implementation of a PM program will extend equipment life, reduce repair and replacement costs, and ensure that equipment is safe to operate. As reflected in the condition of the cranes we observed and the reports we reviewed, the MSS PM program was clearly inadequate. More important, Stennis used cranes that were not safe to operate, which increased the risk of loss or harm to personnel and assets essential to the space propulsion program.

## **Recommendations, Management's Response, and Evaluation of Response**

**The Director, John C. Stennis Space Center, should:**

**12. Direct the MSS to schedule, perform, document, and review PM as required by NSS/GO-1740.9B, Stennis PM policies and procedures, and the MSS contract.**

**Management's Response.** Concur. MSS shall be directed to schedule, perform, document, and review PM in accordance with the contract requirements, which includes compliance with NSS/GO-1740.9b and Stennis policies.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. We ask Stennis to provide additional details describing how it will direct MSS to perform PM tasks and to provide a planned completion date for providing the direction. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**13. Increase Government surveillance of the MSS PM program for cranes to ensure compliance with NSS/GO-1740.9B and Stennis PM policies and procedures.**

**Management's Response.** Concur. See the response to Recommendation 4. Additionally, NASA's Maintenance and Operations Branch of the Stennis Center Operations and Support Directorate monitors the PM program.

**Evaluation of Management's Response.** Management's planned actions are responsive to the recommendation. As for recommendation 4, management should provide us a planned date for implementing its surveillance plan. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**14. Direct the Manager, Safety and Mission Assurance, to coordinate with appropriate Center organizations to track and implement corrective actions for recommendations from various external and internal reviews concerning crane PM deficiencies.**

**Management's Response.** Concur. The Manager, Safety and Mission Assurance, will collect, track, and facilitate closure of all existing issues documented in previous external and internal reviews.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. However, management should provide us a planned completion date for closing the recommendations from previous external and internal reviews. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

## **Finding E. Wire Rope Inspections**

MSS did not perform wire rope inspections in accordance with NASA standards. Inadequate inspections occurred because (1) MSS did not follow inspection procedures and (2) Stennis did not provide adequate surveillance of wire rope conditions. As a result, contractors used cranes with unsafe rope conditions, increasing the risk of lifting failures and harm to personnel and/or assets.

### ***Standards for Performing Inspections***

NSS/GO-1740.9B requires monthly wire rope inspections with emphasis on deterioration and damage. Stennis Technical Standard 1787, "Maintenance Instruction, Wire Rope, Chain, and Link Inspection," requires that the entire length of wire ropes be inspected for reductions in diameter, breaks, kinks, or corrosion. In addition, Stennis Standard Operating Procedure 960, "Inspection and Maintenance of Wire Rope, Slings, and Hooks," provides that cranes will not be used unless wire ropes have been inspected within the last 30 days. Finally, SPG 8715.1 requires that the buddy system<sup>42</sup> be used for hazardous operations, including heavy hoisting and personnel lifting.

### ***Scheduling and Performing Wire Rope Inspections***

**Scheduling and Performing Inspections.** MSS did not schedule monthly wire rope inspections as required. For example, MSS completed two wire rope inspections on a mobile crane in May and August 2000, but did not perform any inspections in June or July. Similarly, MSS completed two inspections on another mobile crane in May and July, and one in June, but did not perform inspections in February or April.

We observed MSS perform wire rope inspections on three cranes. The two inspectors generally followed NASA standards<sup>43</sup> including the recording of required multiple rope measurements. However, MSS inspectors did not follow the standards on inspections prior to our observations. Inspectors recorded only one wire rope measurement on each of four work orders reviewed and did not use the buddy system on three of those work orders.

We reviewed work orders for 161 wire rope inspections performed from September 1999 through November 2000. MSS did not record multiple wire rope measurements on 150 (93 percent) of the inspections, and only 5 (3 percent) inspections addressed the wire rope condition. Also, inspectors did not use the buddy system for 120 (75 percent) of the inspections.

We also identified significant labor variances between inspections by a single employee and those using the buddy system. Specifically, inspections performed by one employee

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<sup>42</sup> The buddy system refers to the use of two or more persons to perform hazardous operations.

<sup>43</sup> MSS inspectors did not disconnect the cranes' power sources as required by Technical Standard 1787.



required from 30 minutes to 2 hours, while inspections using the buddy system required from 2 to 6 hours. The labor variances provided further evidence that MSS inconsistently followed procedures for conducting wire rope inspections.

**NACB Inspections.** After its May 2000 inspection, the NACB reported wire rope problems on some critical lift cranes. MSS inspectors had not detected those problems, thus raising our concerns with the adequacy of MSS inspections. For example, the NACB found broken wires on a mobile crane (crane number 130-106). MSS inspectors did not identify any problems with the crane's wire rope during their March and May 2000 inspections. MSS replaced the wire rope on May 23, 2000.

The NACB also reported a kink in the wire rope of a bridge crane (crane number L-56). MSS performed four inspections prior to the NACB's inspection; however, MSS did not identify any rope problems. The last MSS inspection occurred on May 22, 2000, after the NACB inspection; therefore, MSS should have identified the same problems found by the NACB. MSS replaced the wire rope on June 19, 2000.

Finally, the NACB found wire rope clips installed backwards on a crane at the E-1 Test Stand. Four MSS inspections performed from February through May 2000 did not identify problems with the clips. Again, the May MSS inspection results should have mirrored the NACB's findings. MSS subsequently corrected the rope clip installation.

### ***Government and Contractor Oversight of Wire Rope Inspections***

Similar to the lack of oversight on PM, we found no evidence of Government surveillance by Stennis or DCMA with respect to wire rope inspections. We also found no evidence of safety oversight by MSS.

### ***Conclusion on Wire Rope Inspections***

The NACB report combined with our observations showed that MSS did not perform adequate wire rope inspections. Although MSS corrected rope deficiencies subsequent to the NACB report, inspection personnel should have identified and corrected those crane deficiencies as part of the normal, routine inspection process. Operating cranes with defective or improperly installed ropes could have resulted in further lifting failures at Stennis and harm to assets and/or personnel.

## **Recommendations, Management's Response, and Evaluation of Response**

**The Director, John C. Stennis Space Center should:**

**15. Direct MSS to schedule, perform, document, and review wire rope inspections in accordance with NSS/GO-1740.9B, Stennis policies and procedures, and the MSS contract.**

**Management's Response.** Concur. Since wire rope inspections are a PM function, MSS shall be directed to perform this function as described in the response to Recommendation 12.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. As for recommendation 12, management should provide us additional details describing how it will direct MSS to perform wire rope inspections and a planned completion date for providing the direction. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

**16. Increase Government surveillance of wire rope inspections to ensure the inspections are completed in accordance with applicable NASA standards.**

**Management's Response.** Concur. See the response to Recommendation 4.

**Evaluation of Management's Response.** Management's planned action is responsive to the recommendation. As for recommendation 4, we ask Stennis to provide us a planned completion date for implementing its surveillance plan. The recommendation is resolved, but will remain undispositioned and open for reporting purposes until corrective actions are completed.

## **Appendix A. Objectives, Scope, and Methodology**

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### **Objectives**

The overall objective of the audit was to determine whether Stennis and its contractors properly managed the Lifting Devices and Equipment (LDE) program. Specifically, we determined whether:

- Stennis safely performed critical lifts,
- LDE operators were properly trained and certified,
- personnel operated cranes in a safe manner,
- Mississippi Space Services (MSS) complied with maintenance requirements, and
- MSS performed adequate wire rope inspections.

### **Scope and Methodology**

Stennis had 83 cranes and hoists, 23 that were classified as critical lift cranes. Of the 83, there were 5 mobile cranes, 35 hoists, and 43 fixed (jib, auxiliary derrick, derrick, or bridge) cranes. To satisfy our objectives, we reviewed available documents and records for all 5 mobile cranes and 14 of the 44 fixed cranes. We did not review slings, hooks, or other crane accessories, except to verify the inventory of slings. We verified the accuracy and completeness of the LDE records and identified one crane that was not included in the Center's inventory.

We limited our review to the three major contractors (Lockheed-Martin Space Operations-Stennis Programs (Lockheed Martin), MSS, and The Boeing Company-Rocketdyne Propulsion and Power (Boeing)) that operate and maintain LDE at Stennis. We did not include cranes owned or operated by Stennis tenants in our review. We interviewed Headquarters, Stennis, and contractor Safety and Mission Assurance (S&MA) officials associated with the operation, maintenance, and/or inspection of LDE. We also reviewed NASA, Stennis, and contractor standards and guidelines applicable to the operation, maintenance, and inspection of LDE. We examined (1) previous reports related to Stennis LDE operations to include Headquarters and Center S&MA reports, Defense Contract Management Agency (DCMA) contract surveillance reports, and contractor safety and quality assurance reports, (2) reports for reviews by external organizations contracted for by the Center, and (3) reports issued in 1999 and 2000 on mishaps involving cranes.

Audit field work consisted of reviews and observations of the following:

- Critical lift procedures and records to determine whether Stennis complied with the critical lift requirements of NSS/GO-1740.9B and SPG 8715.1.

## **Appendix A**

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- Lockheed-Martin, MSS, and Boeing training and certification data for operators and riggers to determine whether personnel were trained and certified in accordance with NASA, Stennis, and contractor requirements.
- Crane logbooks for mobile cranes and derricks to identify problems noted by operators during daily inspections and to determine the objects lifted during operations.
- Preventive maintenance and wire rope inspection procedures and a sample of work orders documenting work performed from September 1999 through October 2000 to determine whether MSS complied with crane maintenance and inspection requirements.
- Labor, material, and other contract charges related to maintenance and inspections to determine costs associated with those activities.
- Visual inspections of fixed and mobile cranes to identify safety deficiencies.

### **Management Controls Reviewed**

We reviewed management controls related to the classification and performance of critical lifts and the training, testing, and certification of crane operators and riggers. Additionally, we reviewed controls related to documenting and reporting crane deficiencies, and scheduling, performing, and documenting crane maintenance and inspections. We also reviewed the safety responsibilities delegated to the DCMA for surveillance of the Lockheed-Martin, MSS, and Boeing contracts. We identified internal control weaknesses as identified in the finding sections of the report.

### **Audit Field Work**

We performed field work from October 2000 through June 2001 at Stennis and NASA Headquarters. We performed the audit in accordance with generally accepted government auditing standards.

## Appendix B. Summary of Process Verification Reviews

Process Verification Team Safety Concern	1997	1999	2000
Lack of staffing in the Safety and Mission Assurance (S&MA) office.	X	X	--
Lack of S&MA support at the E Complex and other areas.	--	X	--
The Stennis Safety Manual does not reference NASA Handbook 1700.1 (V-1B), NASA Safety Standards 1740.11 and 1740.12.	X	--	--
Annual NASA safety inspections of resident agencies and contractor safety programs are behind schedule.	X	--	--
Stennis does not have a civil service program manager to ensure configuration management and control of lifting devices and equipment (LDE). Roles and responsibilities of LDE manager are not defined.	X	X	X
Stennis LDE policies and procedures are not current.	X	X	X
Stennis LDE inventory is not current.	X	X	X
Stennis Procedures and Guidelines (SPG) 8715.1, Part I, LDE, has not been finalized.	X	--	--
Stennis does not have one lead contractor managing its LDE program.	--	X	--
Stennis Standard 99-016 does not clearly define LDE configuration management, including record keeping.	--	--	X
SPG 8715.1, Part I, Section 2.18, does not require an LDE committee chaired by the LDE manager or identify committee responsibilities.	--	--	X
Some of Stennis' LDE was not tagged and/or labeled, and slings were not inventoried or certified.	--	--	X
LDE maintenance records and supporting documentation were difficult to locate and may not exist.	--	--	X
Stennis did not have a long-term, comprehensive, sustainable LDE program.	--	--	X

## Appendix C. North American Crane Bureau Inspection Results

In May 2000, the North American Crane Bureau (NACB) recommended that to assure operational readiness, Stennis should establish a detailed maintenance and inspection program, with special emphasis on wire ropes. The NACB also reported that deficiencies and safety concerns, such as no capacity markings or warning tags, lack of lubrication, and rust were prevalent throughout the facility. The following table summarizes the NACB's findings.

**Summary of NACB Findings**

<b>Critical Lift Equipment</b>	<b>No Warning Tag</b>	<b>Need Lubricant</b>	<b>No Operator Manual</b>	<b>Equipment Wear/Rust</b>	<b>Hydraulic Oil Low</b>	<b>Wire Rope Problem</b>	<b>No or Poor Inspection</b>	<b>Missing Parts</b>	<b>Poor Clearance</b>	<b>Leaking Parts</b>	<b>No Load Rate Marking</b>	<b>Loose Debris Present</b>	<b>No Load Chart</b>	<b>No Fire Extinguisher</b>	<b>No Hand Signal Chart</b>	<b>Mechanical Problem</b>
Gaffrey, 4 Ton Hoist	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Terex, 75 Ton Mobile Crane	--	--	X	X	X	X	--	--	--	--	--	--	--	--	--	--
Shepard, 25 Ton Crane	X	--	--	X	--	X	X	X	--	--	--	X	--	--	--	--
Reading, 15 Ton Crane	X	X	--	--	--	--	--	--	X	X	X	X	--	--	--	--
Shepard Niles, 25 Ton Crane	--	--	--	X	--	--	--	--	X	--	--	--	--	--	--	--
Stewart Systems, 25 Ton Crane	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dixie Crane, 10 Ton Crane	X	X	--	--	--	X	--	--	--	X	--	--	--	--	--	X
P&H, 10 Ton Hoist	X	--	--	X	--	--	--	--	--	--	X	--	--	--	--	X
Robbins & Myers, 3 Ton Monorail	X	--	--	--	--	X	--	--	--	--	X	--	--	--	--	X
American Hoist Derrick	--	X	X	X	--	X	--	--	--	--	--	--	X	--	--	--
American Hoist, 175 Ton	--	--	X	--	--	--	--	--	--	--	--	--	X	X	X	--
American Hoist Derrick, 200 Ton	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Yale Hoist, 20 Ton	X	--	--	X	--	--	--	--	--	--	X	--	--	--	--	--
American Hoist, 37.5 Ton	--	--	X	--	--	--	--	--	--	X	--	--	X	--	--	--
Dixie Crane, 5 Ton	X	X	--	X	--	--	--	--	--	--	--	--	--	--	--	X
<u>Terex 8.5 Ton Hydraulic Crane</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<b>Totals</b>	<b>9</b>	<b>6</b>	<b>4</b>	<b>8</b>	<b>1</b>	<b>5</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>2</b>	<b>3</b>	<b>1</b>	<b>1</b>	<b>4</b>

## Appendix D. Management's Response

National Aeronautics and  
Space Administration  
**John C. Stennis Space Center**  
Stennis Space Center, MS 39529-6000



Reply to Attn of: AA00

September 24, 2001

TO: NASA Headquarters  
Attn: W/Assistant Inspector General for Auditing

FROM: AA00/Director

SUBJECT: Management Response to OIG's Draft Report on Safety of Lifting Devices  
and Equipment at Stennis Space Center  
AA-00-048-00

We have reviewed the subject draft report and offer the following comments as to the findings and recommendations contained therein.

**The Director, John C. Stennis Space Center, should:**

**1. Direct all Stennis contractors to conduct critical lifts in accordance with NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Concur. All contractors shall be directed to conduct critical lifts in accordance with NSS/GO 1740.9 and the SSC LDE Management Plan.

**2. Direct the Manager, Safety and Mission Assurance and the LDE Program Manager to perform hazard analyses, mark cranes, and maintain an LDE inventory as required by NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Partially Concur. We concur on new LDE and for procurement of new cranes, a requirement shall be included in the contract for the equipment supplier to provide hazard analyses. Since hazard analyses are primarily utilized in the design phase, and since we have adequate historical data on our existing critical lift cranes, we feel for existing cranes that the most appropriate and value added approach is to perform risk evaluations, in lieu of hazard analyses. The LDE Management Plan requires capacity marking for all cranes and conspicuous markings for all critical lift cranes and a Stennis Work Order (SWO) will be prepared to ensure all cranes are marked as required. An inventory of all lifting devices is currently maintained in the Facility Operations Support Contractor (FOSC) Computerized Maintenance Management System (CMMS). Although an inventory of slings is not required, all contractors have been tasked to maintain an inventory of their rigging gear.

**3. Revise SPG 8715.1 to identify Stennis-unique critical lift requirements.**

**Management's Response:** Concur. The Stennis Space Center Lifting Devices and Equipment Management Plan have been modified to define unique, programmatic critical lifts. Upon final approval this plan will replace the current chapter regarding LDE in SPG 8715.1.

**4. Increase Government surveillance of critical lifting operations to ensure they comply with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Concur. Stennis S&MA office has been tasked to prepare a surveillance plan that will ensure compliance with all requirements of NSS/GO 1740.9 and the SSC LDE Management Plan. The surveillance plan will address training and certification of operators, maintenance of equipment, procurement of new equipment, and surveillance of lifting operations.

**5. Direct MSS to establish and maintain a comprehensive training and certification program for all operators and riggers at Stennis and to ensure that certifications are in compliance with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Partially concur. NASA SSC is establishing a comprehensive training and certification program for all operators and riggers, which will comply with NSS/GO 1740.9 and the SSC LDE Management Plan. Overall responsibility may be assigned to an organization other than MSS.

**6. Increase Government surveillance of contractor compliance with training and certification requirements to ensure compliance with NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Concur. See response to item 4.

**7. Direct the Manager, Safety and Mission Assurance, to track and resolve training and certification recommendations made by both external and internal reviews such as investigation boards, process verification reviews, or independent assessments.**

**Management's Response:** Concur. All training and certification recommendations from external and internal reviews will be addressed in the comprehensive training plan identified in recommendation 5.

**8. Direct contractor personnel, including operators, maintenance and inspection crews, and supervisors, to maintain logbooks for all cranes as required by NSS/GO-1740.9B and SPG 8715.1.**



**Management's Response:** Partially Concur. The SSC LDE Management Plan has incorporated a requirement for operators' daily inspection checklists, in lieu of a logbook, for all cranes. The checklists will be maintained until all open corrective actions are closed. If no discrepancies are noted, the checklists will be deleted after 30 days. Permanent records regarding LDE corrective maintenance will be maintained in the FOSC CMMS system.

**9. Implement promptly the previously recommended corrective actions for reporting and correcting crane and derrick deficiencies.**

**Management's Response:** Concur. The reporting and correcting of crane and derrick deficiencies will be tracked by means of the checklists described in recommendation 8. Permanent records regarding LDE corrective maintenance will be maintained in the FOSC CMMS system.

**10. Prohibit the use of cranes with known hazardous deficiencies as required by NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Concur. Contractors shall be directed to tag out cranes with known hazardous deficiencies.

**11. Increase Government surveillance of contractor compliance with crane operation safety requirements and supporting documentation in accordance with the requirements of NSS/GO-1740.9B and SPG 8715.1.**

**Management's Response:** Concur. See response to item 4.

**12. Direct MSS to schedule, perform, document, and review PM as required by NSS/GO-1740.9B, Stennis PM policies and procedures, and the MSS contract.**

**Management's Response:** Concur. MSS shall be directed to schedule, perform, document, and review PM in accordance with the contract requirements, which includes compliance with NSS/GO 1740.9 and SSC policies.

**13. Increase Government surveillance of the MSS PM program for cranes to ensure compliance with NSS/GO-1740.9B and Stennis PM policies and procedures.**

**Management's Response:** Concur. See response to item 4. Additionally, NASA's Maintenance and Operations Branch of the SSC Center Operations and Support Directorate monitors the PM program.

**14. Direct the Manager, Safety and Mission Assurance, to coordinate with appropriate Center organizations to track and implement corrective actions for**

**recommendations from various external and internal reviews concerning crane PM deficiencies.**

**Management's Response:** Concur. The Manager, Safety and Mission Assurance, will collect, track and facilitate closure of all existing issues documented in previous external and internal reviews.

**15. Direct MSS to schedule, perform, document, and review wire rope inspections in accordance with NSS/GO-1740.9B, Stennis policies and procedures, and the MSS contract.**

**Management's Response:** Concur. Since wire rope inspections are a PM function, MSS shall be directed to perform this function in the response to recommendation 12.

**16. Increase Government surveillance of wire rope inspections to ensure the inspections are completed in accordance with applicable NASA standards.**

**Management's Response:** Concur. See response to item 4.

If there are any questions regarding this response, please contact Mr. Rich Harris, LDE Program Manager, at (228) 688-1632.



Mark Craig  
Acting Director

cc:  
CA00/K. Human  
DA00/R. Dubuisson  
RA00/W. Parsons  
RA82/T. Franklin  
QA00/G. Liebig  
QA00/M. Smiles  
Q/Associate Administrator for Safety and Mission Assurance  
JM/Director, Management Assessment Division  
M/Associate Administrator for Space Flight

## **Appendix E. Report Distribution**

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### **National Aeronautics and Space Administration (NASA) Headquarters**

A/Administrator  
AI/Associate Deputy Administrator  
AA/Chief of Staff  
AB/Associate Deputy Administrator for Institutions  
B/Acting Chief Financial Officer  
B/Comptroller  
BF/Director, Financial Management Division  
G/General Counsel  
H/Associate Administrator for Procurement  
J/Associate Administrator for Management Systems  
JM/Director, Management Assessment Division  
L/Acting Associate Administrator for Legislative Affairs  
P/Associate Administrator for Public Affairs  
R/Associate Administrator for Aerospace Technology  
S/Associate Administrator for Space Science  
U/Acting Associate Administrator for Biological and Physical Science  
X/Director, Office of Security Management and Safeguards  
Y/Associate Administrator for Earth Sciences  
Z/Acting Associate Administrator for Policy and Plans

### **NASA Centers**

Director, Ames Research Center  
Director, Dryden Flight Research Center  
Director, Goddard Space Flight Center  
Director, John H. Glenn Research Center at Lewis Field  
Acting Director, Johnson Space Center  
Director, Kennedy Space Center  
Chief Counsel, John F. Kennedy Space Center  
Director, Langley Research Center  
Director, Marshall Space Flight Center

### **Non-NASA Federal Organizations and Individuals**

Assistant to the President for Science and Technology Policy  
Deputy Associate Director, Energy and Science Division, Office of Management and Budget  
Branch Chief, Science and Space Programs Branch, Energy and Science Division, Office of Management and Budget

## **Appendix E**

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### **Non-NASA Federal Organizations and Individuals (Cont.)**

Managing Director, Acquisition and Sourcing Management Team, General Accounting Office

Senior Professional Staff Member, Senate Subcommittee on Science, Technology, and Space

### **Chairman and Ranking Minority Member – Congressional Committees and Subcommittees**

Senate Committee on Appropriations

Senate Subcommittee on VA, HUD, and Independent Agencies

Senate Committee on Commerce, Science, and Transportation

Senate Subcommittee on Science, Technology, and Space

Senate Committee on Governmental Affairs

House Committee on Appropriations

House Subcommittee on VA, HUD, and Independent Agencies

House Committee on Government Reform

House Subcommittee on Government Efficiency, Financial Management, and Intergovernmental Relations

House Subcommittee on National Security, Veterans Affairs, and International Relations

House Subcommittee on Technology and Procurement Policy

House Committee on Science

House Subcommittee on Space and Aeronautics

### **Congressional Member**

Honorable Pete Sessions, U.S. House of Representatives

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**Report Title:** Final Report on Audit of the Safety of Lifting Devices and Equipment at Stennis Space Center

**Report Number:** \_\_\_\_\_ **Report Date:** \_\_\_\_\_

*Circle the appropriate rating for the following statements.*

	Strongl y Agree	Agree	Neutra l	Disagre e	Strongl y Disagre e	N/A
1. The report was clear, readable, and logically organized.	5	4	3	2	1	N/A
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Excellent

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***How did you use the report?*** \_\_\_\_\_

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***How could we improve our report?*** \_\_\_\_\_

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